3010
HOT - COLD
NOISE GENERATOR

KAY ELEMETRICS CORP
FORMERLY

KAY ELECTRIC CO.

KAY ELEMETRICS CORP

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SECTION I

GENERAL DESCRIPTION

1.1 INTRODUCTION

The Kay Elemetrics Corp Model 3010 Hot-Cold Noise Generator has been designed to provide an accurate source standard for use in the determination of an instruments Noise Figure.

The unit may be provided with the Model 7931 Coaxial Switch which increases the operational speed in the D.C. to 2.5 GHz region of the Generators overall range to 9 GHz. Another 3010 noise generator accessory is the Waveguide Adaptor, which facilitates the connection of Type WR430 waveguide to the switches Type N output connectors.

1.2 SPECIFICATIONS

FREQUENCY RANGE	D.C.-9 GHz.
OUTPUT IMPEDANCE	50 ohms (Nominal).
SWR	1.15:1 Maximum.
DIFFERENTIAL SWR	The distance between the complex impedance points of the hot and cold termination, as plotted on a Smith Chart, should be less than the diameter of a 1.05:1 SWR Circle below and at 7 GHz, and less than the diameter of a 1.10:1 SWR circle above 7 GHz.
TERMINATION TEMPERATURE	
HOT	373.2 degrees K NOTE: See Section 2.4 for accuracy considerations.
COLD	77.3 degrees K NOTE: See Section 2.4 for accuracy considerations.

NOISE TEMPERATURE	Termination Temperature ± Frequency Correction Factor. NOTE: See Section 2.4 for accuracy considerations.
MEASUREMENT ACCURACY	± 0.1 db. NOTE: See Section 2.4 for accuracy considerations.
OPERATIONAL LINE VOLTAGE REQUIREMENTS	115 VAC 10%, 59-63 Hz.
POWER CONSUMPTION	20 watts
WEIGHT	15 pounds
DIMENSIONS	L 20 3/8" x H 9 5/8" x W 9 3/8"
OVEN TEMPERATURE MONITOR	Copper-constantan thermocouple and output jack.
NITROGEN LIFE	3 Hours (Typical).
OUTPUT CONNECTORS	7 mm, Precision Amphenol Type APC-7.
FUSES	1/2 Amp (2each F. B. std.)

1.3 ACCESSORY SPECIFICATIONS (Optional)

Coaxial Switch Model 7931

FREQUENCY RANGE	Full range of 3010 Generator, however, this unit was designed and optimized for use in the D.C. to 2.35 GHz region.
SWR	D.C.-2.15 GHz- - 1.20:1 Maximum. 2.15-2.35 GHz- - 1.15:1 Maximum. 2.35-9 GHz- - 2.00:1 Maximum.
DIFFERENTIAL SWR	3010 generator specifications applicable, only in the 2.15 to 2.35 GHz range.
CONNECTOR (INPUT)	7 mm, Precision Amphenol Type APC-7S.
CONNECTOR (OUTPUT)	Precision Type N Amphenol Type APC-N.
INSERTION LOSS	As marked on switch (0.1 db Nominal)

NOTE

Only when the Switch is securely connected to the output of the generator are the preceeding SWR and Differential SWR specifications valid. Each switch is calibrated for a particular Hot-Cold generator and, therefore, cannot be utilized with any other generator. Connection of any switch to another unit may cause mechanical alignment problems and changes in Output SWR.

Waveguide Adaptor

(Coaxial Type N to WR 430)

FREQUENCY RANGE	2.15-2.35 GHz.
SWR	1.15 Maximum.
INSERTION LOSS	0.1 db Maximum.
INPUT CONNECTOR	Type N, Amphenol APC-N.

1.4 GENERAL DESCRIPTION

Front Panel

COLD OUTPUT CONNECTOR	Output of Cold Termination. (7 mm Precision. See Section 1.2 for specifications.)
HOT OUTPUT CONNECTOR	Output of Hot Termination. (7 mm Precision. See Section 1.2 for specifications.)
NITROGEN LEVEL INDICATORS	
FULL	"FULL" Lamp illuminated when Nitrogen reservoir has attained its maximum capacity.
EMPTY	"EMPTY" Lamp illuminated when the Nitrogen in the reservoir has evaporated to within 1/2" of the cold termination.
OVEN "ON" INDICATOR	Lamp illuminated when the oven is energized.
POWER INDICATOR LAMP	Illuminates when power is applied to all unit functions.

Rear Panel

FUSES	Provide protection for circuitry overloading. (See Section 1.2 for specifications.)
A.C. LINE CORD	3 wire cable and plug for primary power application.

Top

RESERVOIR (DEWAR FLASK) CAP	Used to seal the input filler. Secured by a Wing nut. Clockwise rotation expands inserted portion of cap, insuring a tight seal.
INPUT FILLER LINE	Transports the liquid Nitrogen to the Dewar Flask.

SECTION II

General Operating Instructions

2.1 INTRODUCTION (Precautions)

This section will cover the installation, general operation instructions, and the check-out procedure for the Model 3010 Noise Generator and its accessories. It is suggested that the operator become completely acquainted with the information in this section, as there are many critical points to be observed in gaining the units full operational potential.

It is also suggested that the previous section covering the location and explanation of the operating controls, connectors and indicators be utilized as a prerequisite study and reference point.

Upon receipt of the instrument visually inspect it for any damage that might have occured during shipment. Please report any damage to the carrier and to Kay Elemetrics Corp.

CAUTION

1. Liquid Nitrogen can cause burns upon contact with skin.
2. Use caution when filling the units reservoir.
3. Never operate or store unit without the reservoir cap fitted

4. Always utilize the indicator lights for ascertaining the Nitrogen level. Looking into the reservoir opening, for a visual indication, may be dangerous.

5. Never use water to rinse the reservoir. Water may enter the Cold termination and freeze thus causing SWR errors. In normal usage The liquid Nitrogen will not contaminate the reservoir.

6. Consult the factory Service Department for assistance if cleaning is required.

2.2 CHECK OUT PROCEDURE

2.2.1 TEST EQUIPMENT REQUIREMENTS:

NOTE

Substitutions may be made where comparable equipment is available.

SLOTTED LINE	Hewlett Packard 861A. Slab Line with APC-7 terminating short.
SIGNAL SOURCES (Frequency generator (s) covering the test frequency range. Square wave modulation capability required.)	Hewlett Packard 8614B 1.3-2.4 GHz. Hewlett Packard 8616B 2.4-4.5 GHz. Hewlett Packard 618C 4.5-7 GHz. Hewlett Packard 620C 7-9 GHz.

produce standing-waves in excess of the specifi-cation limits.)

NOTE

All connectors should be tight, clean, and well seated. Any losses caused by improper connections will greatly affect the parameters necessary for accurate measurements.

Adapters should not be used between the attenuator and the slotted line and especially between the Hot/Cold Noise Source and slotted line. Be sure to follow the directions given by the slotted line manufacturer to insure that the detector is operating in its square-law region.

2.2.2 INITIAL UNIT PREPARATION

A. Apply line power and turn unit on.

B. Remove the cap and pour in approximately one-half pint of liquid Nitrogen.

CAUTION

Avoid direct contact with liquid Nitrogen.

C. Insert and tighten the cap. Allow the unit to rest for approximately 2 minutes. At this time, remove the cap and resume filling the unit until the "Full" indicator lamps come on.

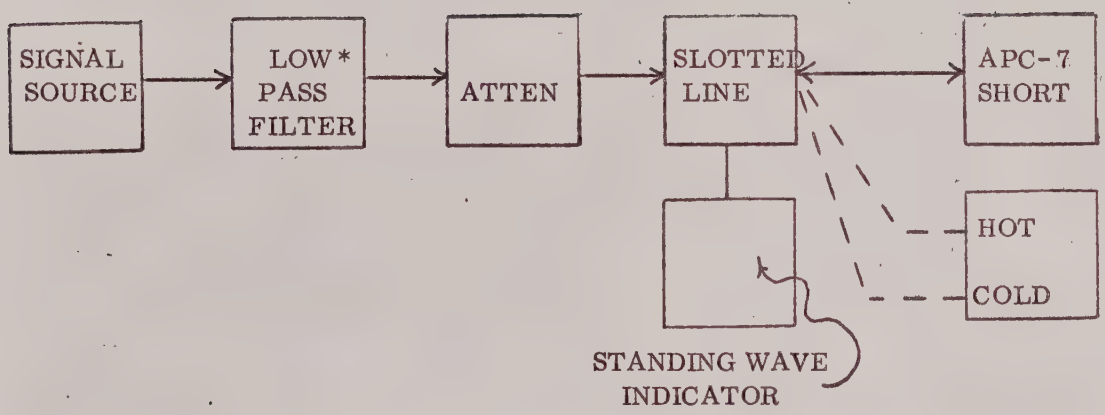
D. Replace and tighten the cap. Allow the unit to rest for approximately 15 minutes (Power on). At this time the Oven indicator lamp will cycle off and on, indicating that temperature stabilization has been achieved.

2.2.3 HOT/COLD NOISE GENERATOR SWR AND PHASE MEASUREMENT

A. Set up the equipment as illustrated in Figure 2.1.

B. Set the signal source for 1.5 GHz.

C. Place the short at the noise source end of the slotted line. Starting from the noise source end of the slotted line adjust for the first peak; then, for the first, and then for the second peak. Take accurate measurements and record your readings in centimeters, using the coaxial connector on the noise source as a reference point.



* Low pass filter needed only if harmonics are great enough to produce SWR's outside of specification limits.

FIGURE 2.1 TERMINATION SWR TEST SET - UP

D. Remove the short and connect the slotted line to the noise source cold terminal. Find the null located between the first peak and second peak of the shorted conditions. Measure also the magnitude of the SWR.

E. Repeat Step D for Hot Terminal.

F. Record all data on Table 2.1.

G. Repeat steps B through E for the following frequencies: 2.0, 2.15, 2.25, 2.35, 3.0, 4.0, 5.0, 6.0, 7.0, 8.0, 9.0 GHz.

H. Measure the D.C. resistance of both the Hot and Cold terminations to within 1 ohm accuracy.

I. Plot both magnitude and phase data on an expanded Smith Chart. Figure 2.2 is given as a sample. The first null under shorted conditions is used as a reference. The amount the Hot and Cold termination nulls moved from the short null is given in centimeters and can be translated into wave lengths. The direction that the Hot and Cold nulls moved in must also be noted; that is, either toward the generator or towards the load. The distance between the complex impedance points of the hot and cold terminations, as plotted on the Smith Chart, should be less than the diameter of a

TABLE 2 .1 TERMINATION SWR - MAGNITUDE & PHASE DATA

SWR MAGNITUDE AND PHASE

FREQUENCY (GHz)	TERMINATION	FIRST PEAK (cm)	FIRST NULL (cm)	SECOND PEAK (cm)	SWR	REMARKS
	SHORT	----				
	COLD					
	HOT					
	SHORT					
	COLD					
	HOT					
	SHORT					
	COLD					
	HOT					
	SHORT					
	COLD					
	HOT					
	SHORT					
	COLD					
	HOT					
	SHORT					
	COLD					
	HOT					
	SHORT					
	COLD					
	HOT					
	SHORT					
	COLD					
	HOT					
	SHORT					
	COLD					
	HOT					
	SHORT					
	COLD					
	HOT					
	SHORT					
	COLD					
	HOT					

GW | DIFFERENTIAL [illegible] PLOT | DATE 2/2/73

SMITH CHART FORM 82 SPR (2-49) | KAY ELECTRIC COMPANY, PINE BROOK, N.J. ©1949 PRINTED IN U.S.A.

IMPEDANCE OR ADMITTANCE COORDINATES

SERIAL NO 45

ITEM 30108

FREQUENCY 2GHz

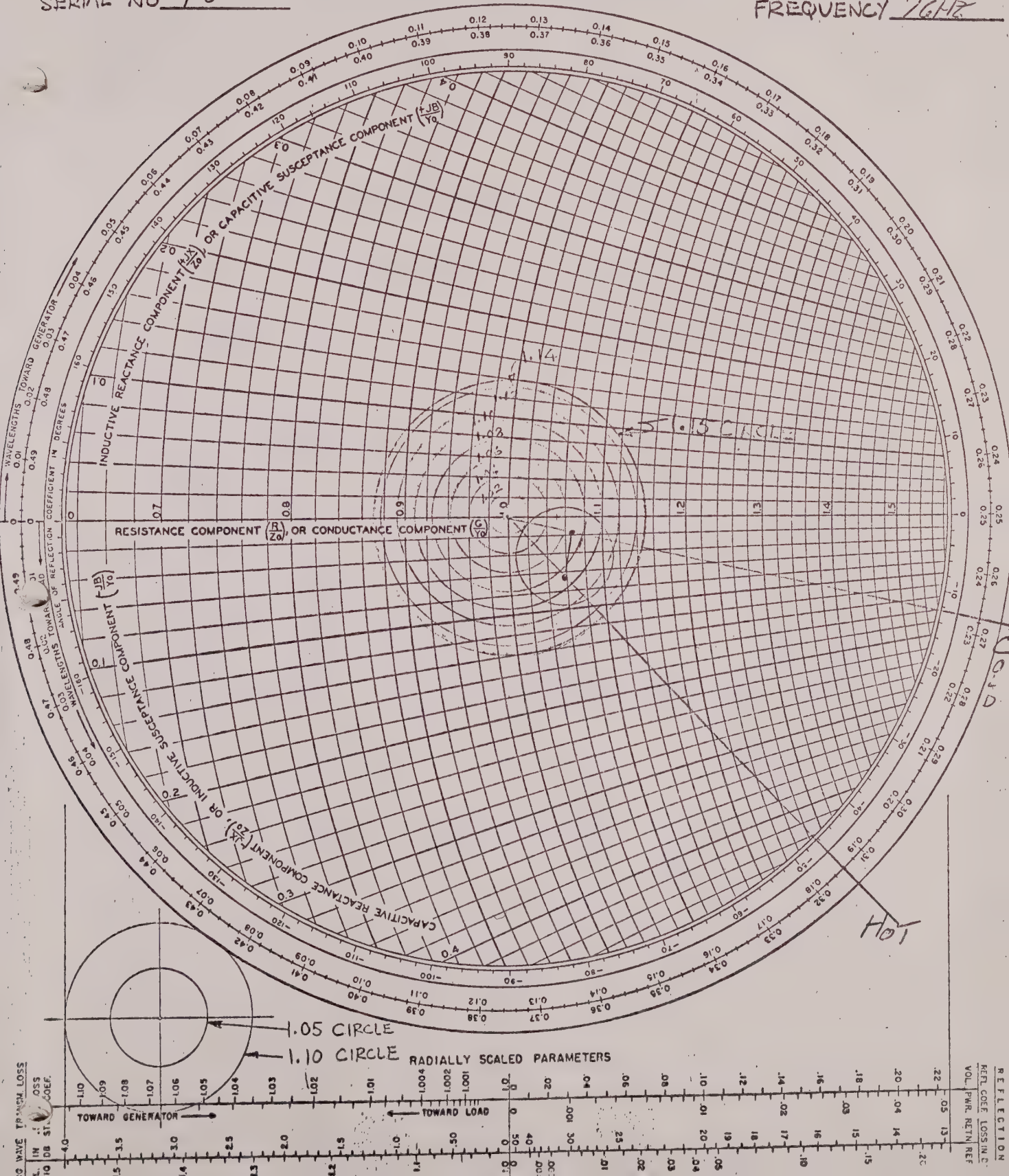


TABLE 2.2

FREQUENCY (GHz)	VSWR		
	SPEC LIMIT	MEASURED POSITION	
		HOT	COLD
1.3	1.2:1		
1.5	↑		
1.7	↓		
1.9	1.2:1		
2.15	1.15:1		
2.25	↑		
2.35	↓		
2.5	1.15:1		
3.0	2:1 ↑		
4.0	↑		
5.0	↑		
6.0	↑		
7.0	↑		
8.0	↑		
9.0	2:1		
Resistance (DC)	43.5 to 57.5		

Switch VSWR (Connected To Matching Hot/Cold Source.)

of a 1.05:1 SWR circle below and at 7 GHz and less than the diameter of a 1.10 SWR circle above 7 GHz.

J. Attach the coaxial switch to the hot and cold terminations and repeat steps B through E for 2.15 GHz Record data on Table 2.2. Plot the data on Smith Chart as in step I.

K. Repeat Step J for the following frequencies: 2.24 and 2.35 GHz.

L. Measure just the magnitude of the SWR of both the hot and cold side of the switch at the following frequencies: 1.3, 1.5, 1.7, 1.9, 2.5, 3, 4, 5, 6, 7, 8 and 9 GHz. Record all data on Table 2.2.

M. Using equipment hook-up as shown in figure 2.3, check coaxial switch correction.

1. Connect amplifier to hot termination. Set Noise Figure to read 1.00 db. Record in Table 2.3.

2. Connect amplifier to cold termination. Read NFM and record on Table 2.3.

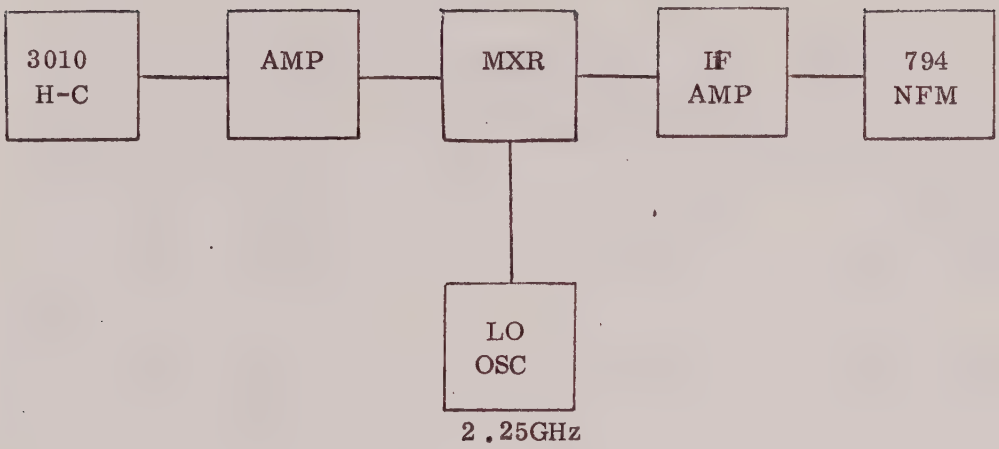


FIGURE 2.3

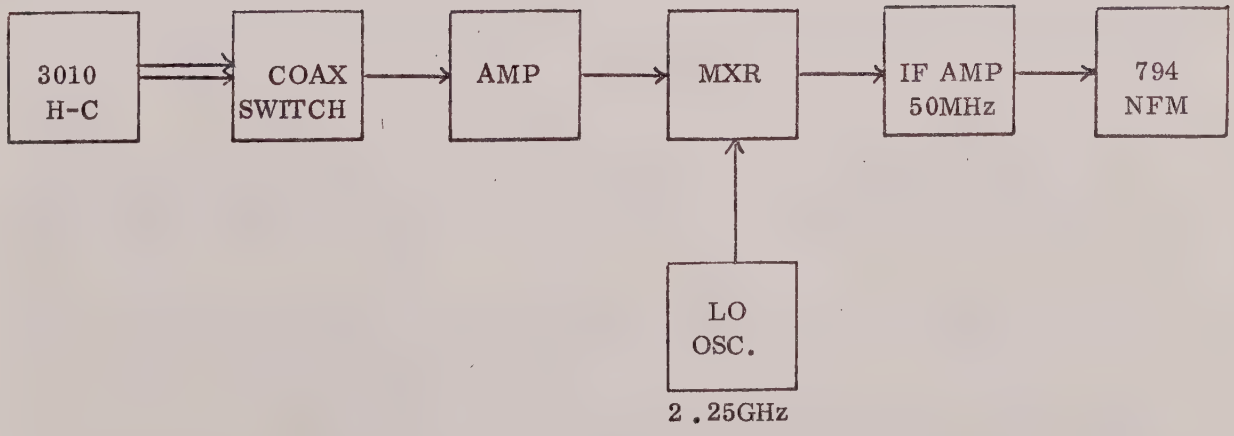


FIGURE 2.4

3. Subtract hot termination from cold termination and enter this in the Y-Factor block in Table 2.3.

4. Insert coaxial switch in set-up as shown in Figure 2.4.

5. With switch in hot position, take a reading on NFM and record in Table 2.3.

6. With switch in cold position, record reading in Table 2.3.

7. Subtract hot reading from cold reading and record in Y-Factor block.

8. Enter switch insertion loss (As found on switch) below Table 2.3.

9. Compute Noise figure with and without the switch.

10. Compute F_{db} for Noise figure and insert in Table 2.0.

11. Comput the error between the calculated F_{db} and the insertion loss as given on the switch. Insert the

TABLE 2.3 SWITCH INSERTION LOSS

OUTPUT MEASURED	HOT OUTPUT (db)	COLD OUTPUT (db)	COMPUTED Y-FACTOR (db)	COMPUTED NOISE FIGURE (db) *
WITHOUT SWITCH				
WITH SWITCH				
(F_{db} with switch - F_{db} without switch)				F_{db} +

Insertion Loss Marked on switch _____ db.

F_{db} -Marked Insertion Loss = _____ db error.

(Error should ± .05db)

$$F_{db} = 10 \log_{10}\left(\frac{1.287-0.266Y}{Y-1} + 1\right)$$

where $Y = \log^{-1}_{10}\left(\frac{Y_{db}}{10}\right)$

2.2.4 COAX TYPE "N" TO WR430 WAVEGUIDE ADAPTER SWR MEASUREMENT.

A. Connect the equipment as shown in Figure 2.5.

NOTE

Adapters should not be used between the attenuator and the slotted line and especially between the coax to Waveguide Adapter and the slotted line. Fittings should be clean and tight. Be sure to follow the directions given by the slotted manufacturer to insure that the detector is operating in its square-law region.

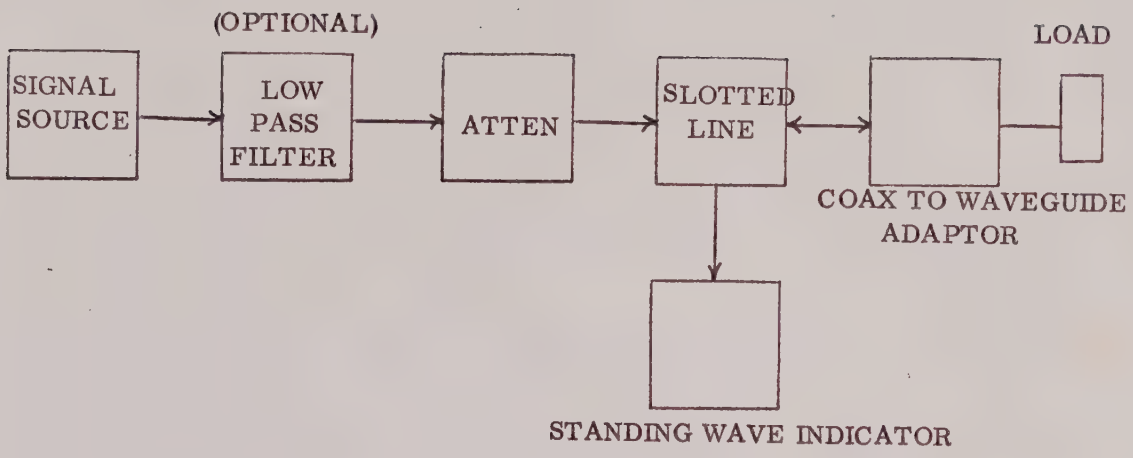


FIGURE 2.5 COAX TO WAVEGUIDE ADAPTOR

TABLE 2.4

FREQUENCY (GHz)	VSWR	
	SPEC LIMIT	MEASURED
2.15	1.15	
2.20	1.15	
2.25	1.15	
2.30	1.15	
2.35	1.15	

B. Set the signal source to 2.15 GHz. Starting from the coax to Waveguide Adaptor end of the slotted line adjust for the first peak and then the first null and read the SWR on the SWR indicator.

C. Repeat Step B at 2.20, 2.25, 2.30, and 2.35 GHz.

D. Record all SWR data on Table 2.4.

2.3 OPERATING INSTRUCTIONS

2.3.1 TEST EQUIPMENT REQUIREMENTS:

NOTE

Substitutions may be made where comparable equipment is available.

LOCAL OSCILLATOR	Low noise type Frequency dependent upon that of unit under test.
R.F. AMPLIFIER (2.2-2.3 GHz, Low Noise)	Avantek, Model AM-2302N
I. F. AMPLIFIER	Optimax, Model AL-1060

NOISE FIGURE METER	Kay, Model 794 Autonode (Automatic Noise Figure Meter)
BALANCED MIXER	Sage Laboratories, Model 2533

WAVEGUIDE APPLICATION

COAX TO WAVEGUIDE ADAPTOR (Type N to WR 430)	Kay Coax-to-Waveguide Adaptor.

NOTE

All connectors should be tight, clean, and well seated. Any losses caused by improper connections will greatly affect the parameters necessary for accurate measurements.

2.3.2 INITIAL UNIT PREPARATION

A. Apply line power and turn unit on.

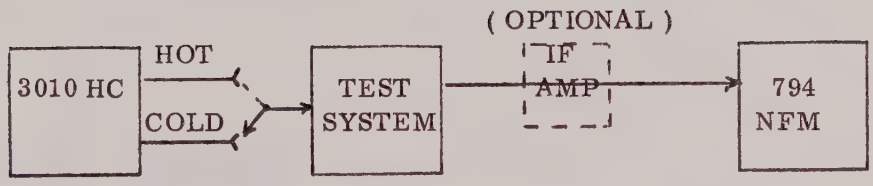
B. Remove the cap and pour in approximately one-half pint of liquid Nitrogen.

CAUTION

Avoid direct contact with liquid Nitrogen!

C. Insert and tighten the cap. Allow the unit to rest for approximately 2 minutes. At this time, remove the cap and resume filling the unit until the "Full" indicator lamps come on.

D. Replace and tighten the cap. Allow the unit to rest for approximately 15 minutes (Power on). At this time the Oven indicator lamp will cycle off and on, indicating that temperature stabilization has been achieved.



0 . 01db Y - FACTOR RESOLUTION

SYSTEM UNDER TEST AT IF FREQUENCY

FIGURE 2 . 6 NOISE MEASURMENT USING THE KAY 794 AUTOMATIC NOISE FIGURE METER AS A PRECISION RECEIVER.

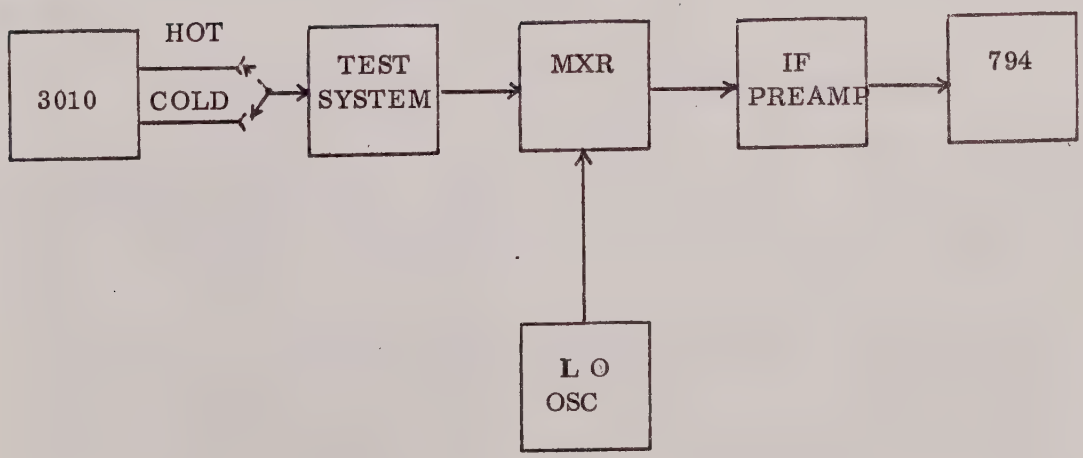


FIGURE 2 . 7 NOISE MEASURMENT AT RF FREQUENCY

2.3.3 NOISE MEASUREMENT

NOTE

The methods covered in this section are presented in the order of the resolution they provide. The alternate methods are given for situations where, the equipment utilized in the High resolution methods is not available.

A. Intermediate Frequency Method (High resolution)

In Figure 2.6 a setup is shown using the Kay 794 Automatic Noise Figure Meter as a precision receiver. The 794 can measure Y-Factor within an accuracy of ± 0.15 db. Y-Factor resolution is 0.01 db. The effective input noise temperature resolution is 1 degree K or less, for effective noise temperatures of 160 degrees K and below.

1. Depress the Manual "Read Y" switch to activate the Y-Factor circuitry of the Noise Figure Meter. (Observe input level requirements.)

2. Connect the system under test to the hot terminal of the noise generator.

3. Adjust the "Manual Gain/Y Cal" control for a 1.00 db reading on the Automatic Noise Figure Meter read out.

4. Now connect the system under test to the cold terminal of the noise generator.

5. Read the number on the read out of the Automatic Noise Figure Meter and subtract 1. The result is the Y factor in decibels.

NOTE

Observe the input level requirements of the Automatic Noise Figure Meter. See the Automatic Noise Figure Meter manual for specifics. The system gain and noise level will determine if an IF amplifier is necessary.

The noise figure of the IF amplifier and mixer will add a certain amount of error to the noise figure as read for the system under test. See Section 2.5 for a correction equation.

B. Radio Frequency Method (High resolution) Set up as in Figure 2.7, use the method of Section 2.3.3. See Section 2.5.8 for a discussion of single sideband vs double sideband noise.

C. IF and RF Noise Measurement (Alternates) Y Factor measurement accuracy can be made a function of a precision attenuator instead of the noise figure meter.

1. Set up as in Figure 2.8 with the cold output of the noise generator fed into the system under test.

2. Depress the Manual "Read Y" switch to activate the Y factor circuitry of the Noise Figure Meter. (Observe input level requirements.)

3. Adjust the "Manual Gain/Y Cal control of the Noise Figure Meter for a 6.0 db Meter indication.

4. Make note of the attenuator setting.

5. Switch to the "Hot" output of the noise generator. The meter indication will decrease.

6. Switch in attenuation until the meter indication again reads 6.0 db.

7. The resulting difference in the two attenuator readings will be the Y-factor in db.

D. General IF and RF Measurement (Alternates) Figure 2.9 provides a general test set up. The addition of a Local Oscillator and Mixer as in Figure 2.8 will provide RF test capability. Proceed as in "IF and RF Noise Measurement (Alternates)". Steps 2 and 3 refer to performance of the Kay 794 Automatic Noise Figure Meter. They should be deleted, in this case, and the meter used should read mid-scale. This is obtained

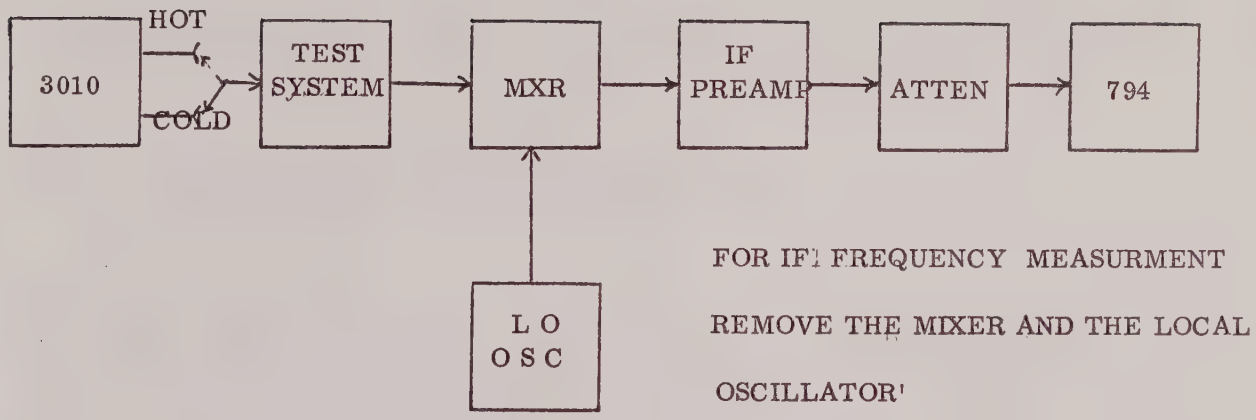


FIGURE 2.8 ALTERNATE NOISE MEASURMENT SET - UP SYSTEM AT RF FREQUENCY

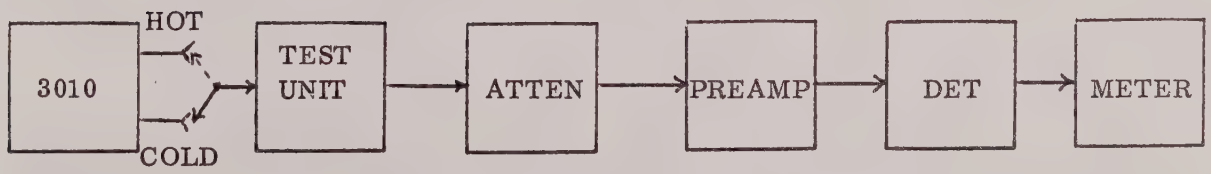


FIGURE 2.9 GENERAL TEST SET - UP FOR NOISE MEASURMENT

2.4 Y-FACTOR CONVERSION TO NOISE FIGURE AND EFFECTIVE INPUT NOISE TEMPERATURE.

2.4.1 Y-Factor Conversion To Noise Figure.

Y-Factor, as determined in Section 2.3, can be converted to Noise Figure by using the following method:

A. First the Y-Factor (in decibels) must be converted to a power ratio, this is done with the aid of Equation 2.1a.

$$Y = \text{Log}_{10}^{-1} \; -1 \; \frac{Y_{db}}{10} \qquad (2.1a)$$

B. Equation 2.1b is used for computing the Noise Figure of the system under test. For a higher degree of accuracy, see Equation 2.3 under Section 2.5.

$$F = \frac{1.287 - 0.266\,Y}{Y - 1} + 1 \qquad (2.1b)$$

C. Noise Figure may be converted into decibels by using Equation 2.1c.

$$F_{db} = 10 \text{ Log}_{10} F \qquad (2.1c)$$

2.4.2 Y-Factor Conversion To Effective Input Noise Temperature.

The effective input noise temperature of the system under test is determined with aid of Equation 2.2. For a higher degree of accuracy see Equation 2.4 in Section 2.5. ("Y" is, again, a power ratio.)

$$T_e = \frac{295.9}{Y - 1} - 77.3 \qquad (2.2)$$

2.4.3 Y-Factor Conversion To Noise Figure and Effective Input Noise Temperature (Graph Method).

Instead of calculating Noise Figure and Effective Input Noise Temperature, these values, may be directly read on the graphs in Figures 2.10 and 2.11.

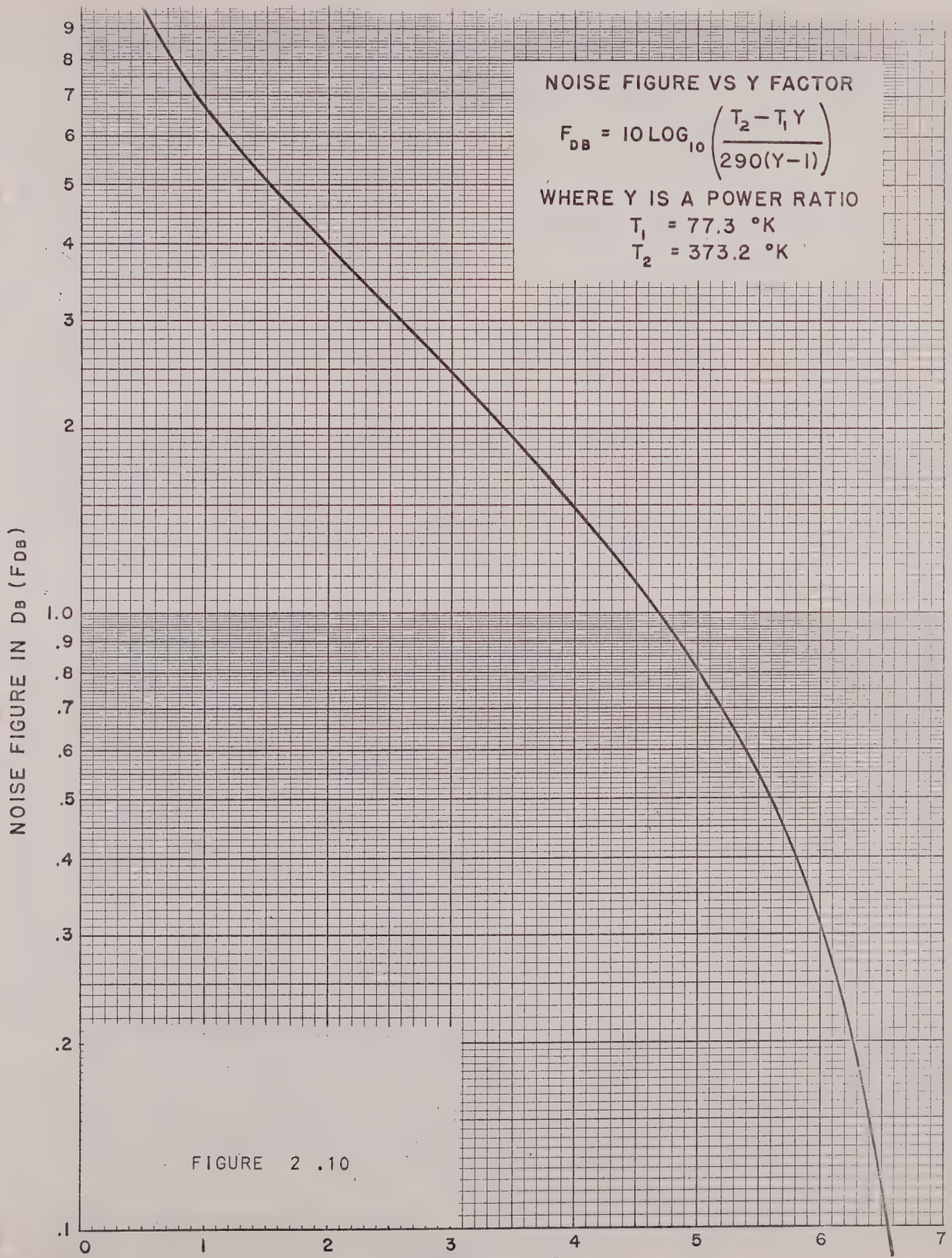
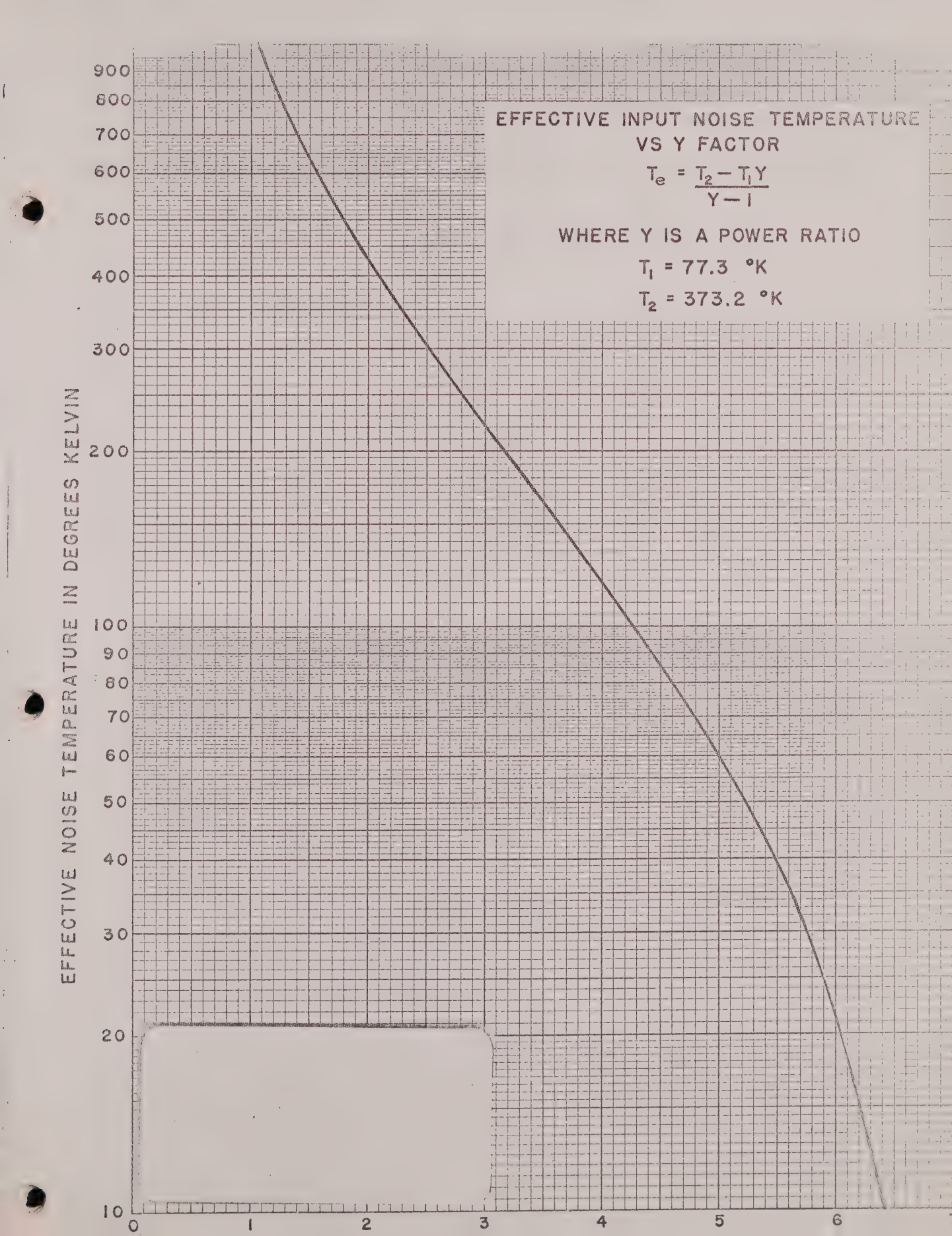

NOISE FIGURE VS Y FACTOR
$F_{DB} = 10 \log_{10}\left(\frac{T_2 - T_1 Y}{290(Y-1)}\right)$
WHERE Y IS A POWER RATIO
$T_1 = 77.3\ ^\circ K$
$T_2 = 373.2\ ^\circ K$
NOISE FIGURE IN DB (F_{DB})
9
8
7
6
5
4
3
2
1.0
.9
.8
.7
.6
.5
.4
.3
.2
.1
0
1
2
3
4
5
6
7
Y-FACTOR IN DB

FIGURE 2 .10


EFFECTIVE INPUT NOISE TEMPERATURE
VS Y FACTOR
$T_e = \frac{T_2 - T_1 Y}{Y - 1}$
WHERE Y IS A POWER RATIO
T_1 = 77.3 °K
T_2 = 373.2 °K
EFFECTIVE NOISE TEMPERATURE IN DEGREES KELVIN
900
800
700
600
500
400
300
200
100
90
80
70
60
50
40
30
20
10
0
1
2
3
4
5
6

2.5 ACCURACY CONSIDERATIONS

2.5.1 The Effect of R.F. Losses On Termination Temperature.

The correction data shown in Figure 2.12 is the result of an investigation into the effects of small R.F. losses between the actual termination and the front panel connectors. The losses are caused by the finite conductivity of the transmission system between these two points. To use this data simply modify the rated output temperature, of each termination, in accordance with the graph in Figure 2.12 and calculate the noise performance using Equations 2.3 and 2.4.

$$F = \frac{T_2 - YT_1}{290(Y-1)} + 1 \qquad (2.3)$$

$$T_e = \frac{T_2 - YT_1}{Y - 1} \qquad (2.4)$$

T_1 Temperature of the Cold Termination (Degrees Kelvin).

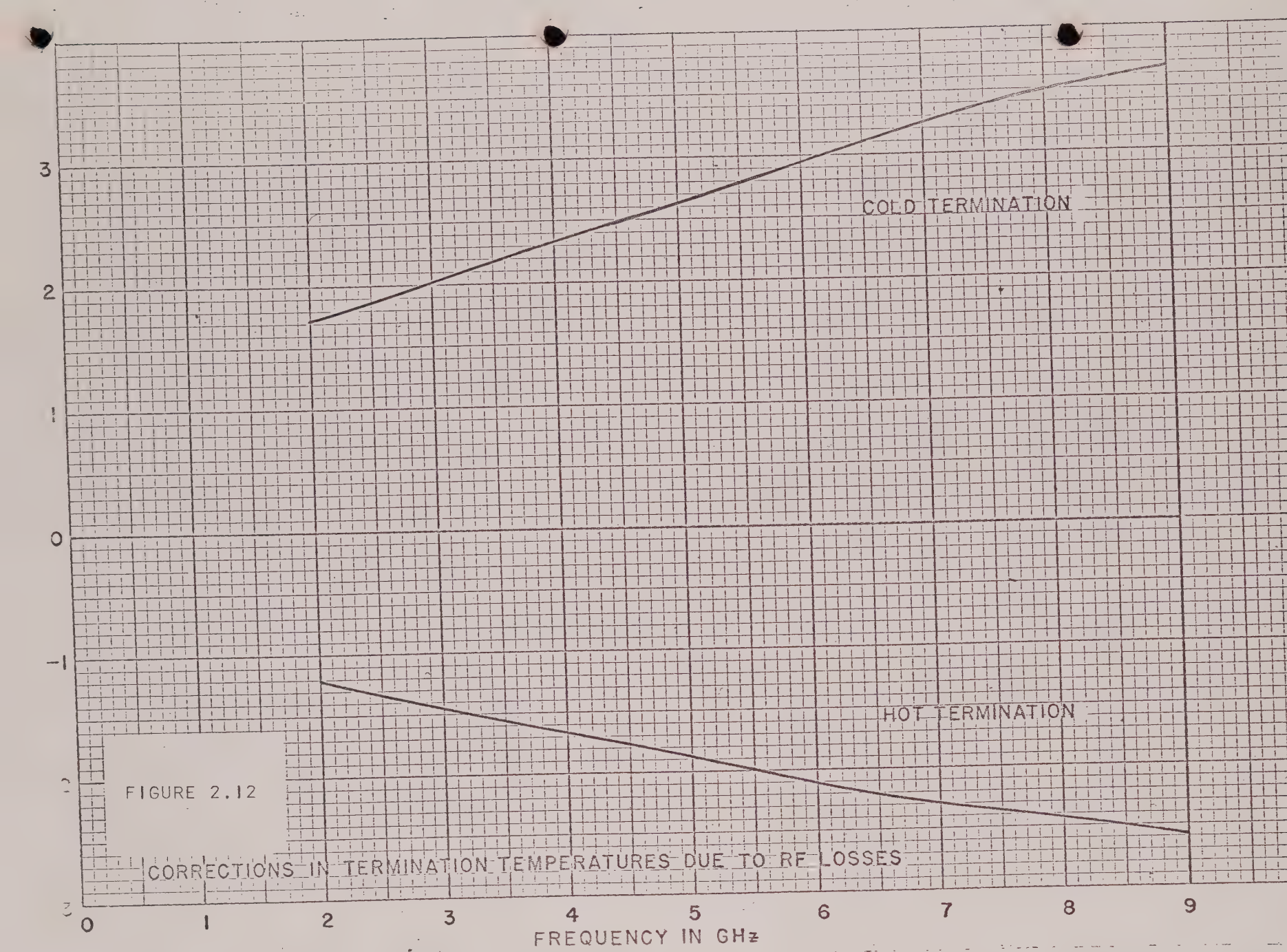


FIGURE 2.12

CORRECTIONS IN TERMINATION TEMPERATURES DUE TO RF LOSSES

T_2 Temperature of the Hot Termination. (Degrees Kelvin)

Y Y-Factor (Expressed as a power ratio).

T_o Ambient temperature (Use 290 Degrees Kelvin)

T_e Effective input noise temperature of the system under test. (Degrees Kelvin)

F Noise Figure (Expressed as a power ratio. Use Equation 2.1c for conversion to decibels)

2.5.2 Effects Of Liquid Nitrogen Contamination on Termination Temperature.

A. Initial Purity of Liquid Nitrogen.

Contamination can seriously affect the boiling point of liquid Nitrogen. This change in temperature will adversely affect the accuracy of the 3010 noise generator's cold termination output. For maximum accuracy the purity of the liquid Nitrogen should be checked with the supplier.

B. Oxygen Contamination.

Oxygen, present in the air, will condense at a temperature about 11 degrees (Kelvin) higher than that of boiling liquid Nitrogen. Exposure of the Nitrogen to Oxygen can result in a mixing of these two elements. This mixture will boil at a temperature higher than that of pure liquid Nitrogen, causing Cold termination temperature error. It, therefore, is suggested that the filling procedure in Section 2.3 be closely followed. This will minimize the probability of such contamination.

C. Foreign Matter.

Foreign matter, even in small amounts, while it may not be substantial enough to alter the liquid Nitrogen boiling temperature, it may settle on, or in the area of, the termination. There it may act as an insulator thus changing the temperature to which the termination is subjected. All possible care should be taken to insure that no foreign matter, of any sort, is admitted to the 3010 noise generator's reservoir. Receptacles and storage containers are prone to the addition of foreign matter especially when uncovered.

2.5.3 Effects of Atmospheric Pressure On Termination Temperature.

At sea level, pure liquid Nitrogen boils at 77.3 degrees Kelvin. (760 mm of Hg). A decrease in atmospheric pressure, such as encountered at high altitudes, will reduce this boiling point by about 0.3 degrees Kelvin per 1000 feet above sea level. At an altitude of 5000 feet, an error of less than -0.03 db would be introduced to the measured value of noise figure. Equation 2.5 gives the actual amount of change in the liquid Nitrogen boiling point temperature.

$$T = 19 \log_{10} \frac{P}{760} \qquad (2.5)$$

T Amount of change in the boiling point of liquid Nitrogen.

P Ambient atmospheric pressure. (This is stated in terms of millimeters of Mercury in a standard Torricelli mercurial barometer.)

At this point reference can be made to Section 2.5.1 for conversion into terms of Frequency correction.

2.5.4 MAXIMUM TERMINATION TEMPERATURE ERROR (UNDER NORMAL SEA LEVEL CONDITIONS.)

Taking proper handling and filling techniques into consideration, the operator can expect maximum cold temperature errors of less than +3.0 degrees Kelvin. The hot termination is held within -3 to +2 degrees of 373.2 degrees Kelvin. Translated into noise figure error, the worst-case errors would be approximately +.08 and -.015 db for noise figures between 0 and 10 db.

NOTE

A Hot/Cold Noise Figure measurement error Chart can be found in the literature.[2]

2. Reference: See "Microwave Engineers Handbook, Vol. 2, Page 126, Publisher: Artech House Inc.

2.5.5 Effects Of Hot To Cold Termination SWR's On Y-Factor Indications

The SWR's of the Hot and Cold terminations are held to a minimum and the terminations are matched at the factory for SWR magnitude and phase. (See Section 1.2 for differential SWR specifications) With some negative resistance devices such as parametric amplifiers, even a small change in source impedance may have a significant effect on the gain of the device. This change in amplifier gain will induce a calculable amount of error in the Y-Factor readings. Equation 2.6 provides the means for determining the true Y-Factor. G is ascertained by coupling a test signal through a 20db directional coupler and into the amplifier. One at a time, the Hot and Cold outputs are connected to the directional coupler's main input.

CAUTION

The tester should insure that limiting, of the test signal, does not occur in the system.

The amplifier gain resulting from both cases is noted at this time for injection into Equation 2.6.

$$\frac{\Delta G}{G} \quad \frac{\Delta Z_o}{Z_o} \, G \qquad (2.6)$$

G = Difference in an amplifier gain when one and then the other noise generator output, along with a test signal, is coupled into it.

G = Amplifier's power gain.

Z_o = Source impedance.

True or actual Y-Factor can be found with the aid of Equation 2.7.

$$Y = Y_a - \Delta G \qquad (2.7)$$

Y = True Y-Factor (Expressed in decibels.)

Y_a = Apparent or uncorrected Y-Factor. (In db)

A possible way around this problem would be to place an isolator between the noise source and the amplifier under test. The insertion loss of the isolator will add directly in db to the overall system noise figure contributions, and therefore, must be subtracted from the measured value of the noise figure.

2.5.6

Effects of Additional Stages Or Components On Noise Figure Readings.

Certain test situations require the addition of amplifiers and/or mixers between the test unit and the Automatic Noise Figure Meter. These added stages will consitute error, especially to the low gain amplifier testing. Friiss' formula provides the means for computing the actual or true Noise figure (as a power ratio) of the unit under test.[3]

Equation 2.8a shows the relationship of the factors involved in measured or apparent Noise Figure readings.

$$F = 1 + (F_1 - 1) + \left(\frac{(F_2 - 1)}{G_1} + \frac{(F_3 - 1)}{G_1 G_2} + \frac{(F_4 - 1)}{G_1 G_2 G_3} + \ldots \right) \qquad (2.8a)$$

Equation 2.37b derived from 2.37a provides the means for computing the true or actual noise figure of the unit under test.

$$F_1 = F - \left(\frac{(F_2 - 1)}{G_1} - \frac{(F_3 - 1)}{G_1 G_2} - \frac{(F_4 - 1)}{G_1 G_2 G_3} - \ldots \right) \qquad (2.8b)$$

$F_{...}$ = Measured or apparent noise figure.

F_1 = True or Actual noise figure of the unit under test.

F_2, F_3 etc.= Noise figures of other system components which must be considered, such as; mixers and amplifiers. (Sequentially carried out, as required.)

G_1 = Gain of the unit under test (As a power ratio)

G_2, G_3 etc.= Gains of added components expressed as power ratios. (Sequentially carried out, as required.)

The equations under 2.38 can be applied if the system components are expressed in terms of noise temperature.

$$T_e = T_{el} + \frac{T_{e2}}{G_1} + \frac{T_{e3}}{G_1 G_2} + \frac{T_{e4}}{G_1 G_2 G_3} + \ldots\ldots \qquad (2.38a)$$

$$T_{el} = T_e - \frac{T_{e2}}{G_1} - \frac{T_{e3}}{G_1 G_2} - \frac{T_{e4}}{G_1 G_2 G_3} - \ldots\ldots \qquad (2.38b)$$

T_e = Noise temperature for the overall system calculated from the measured Y-Factor.

T_{e1} = Actual or true noise temperature of the unit under test.

T_{e2}, T_{e3} etc. = Noise temperature of the other components in the system (Sequentially carried out as required.

G_1 = Gain of the unit under test.

G_2, G_3 etc. = Gains of other components as power ratios.

3 The equations given in this subsection may be found in "Munford" and "Van Der Ziel's" books on Noise.

$$F_{ss} = \left(1 + \frac{G_{im}}{G_{sig}}\right) F$$

F_{ss} = Desired single sideband noise figure. (Expressed as a power ratio.)

F = Double sideband noise figure as measured. (Power ratio)

G_{im} = Image channel gain. (Power ratio)

G_{sig} = Signal channel gain (Power ratio)

NOTE

A. In a receiver system a narrow band filter may be placed between the amplifier and the mixer for image signal rejection. If this is done, the double sideband noise figure as measured should be used to determine the overall system noise figure. This is true because the filter will eliminate the unwanted sideband of noise coming from the amplifier.

B. Most amplifier manufacturers, unless otherwise noted, provide a double sideband and noise figure rating. The use of Equation 2.8 may be eliminated if a narrow band pass filter is placed between the noise generator and the amplifier under test. Of course, the insertion loss of the filter must be added (in db) to the noise figure as calculated. The filter should be tuned to the signal channel frequency. It also should be ascertained that the mismatch of the filter at the image frequency does not effect the noise generated at the input of the amplifier at the image frequency.

2.5.7
Effect Of Losses Arising From Method(s) Of Coupling From The Noise Generator To The Unit Under Test.

Connectors, adaptors, couplers, cabling etc. may insert a discernable amount of error in noise figure measurement. If it is established that this is true, in a particular test set up, their total insertion loss should be subtracted from the measured or apparent noise figure. Insertion losses and noise figure are stated in decibels. Due to the relative position of the losses, that is, before the input of the unit tested, they are in direct relation to each other, thus allowing simple subtraction.

2.5.8
Effect Of Image Response In Receiver Testing.

Double sideband Receiver Noise figure measurement generally follows the set up illustrated in Figure 2.7. In most conventional receiver applications, the image channel is not normally used to convey signal information. If the amplifier under test has gain at both the signal frequency and the image frequency, its noise figure, as measured, will have an optimistic number. The single sideband noise figure desired can be computed from Equation 2.8 .

SECTION III

THEORY

3.1 INTRODUCTION

In this section we will cover the relationship of the factors involved in the 3010 Hot-Cold generator's production of thermal noise, and the basics of noise measurement. It will deal with these factors in terms of the equations pertinent to their relationship.

3.2 THERMAL NOISE POWER

Thermal noise, sometimes called Johnson or White noise, is defined as; the random motion of free electrons in a conductor, caused by thermal agitation, gives rise to a voltage at the ends of the conductor. In most conductors the frequency components of this noise voltage, uniformly, cover the entire R.F. spectrum.

The available thermal noise power transferred from a conductor or resistive termination to a conjugately matched load is defined in Equation 3.1.

$$N = kTB \qquad (3.1)$$

N = Available Noise Power

k = Boltzmann's Constant (1.38×10^{-23} joules / DEGREE K)

T Temperature (Degrees K)

B Bandwidth of the System under test.

One should note, at this point, that noise power is directly proportional to temperature and that the resistive value of the termination does not affect the available power.

3.3 EFFECTIVE INPUT NOISE TEMPERATURE

The noise temperature at a port is the temperature of a passive conductor having an available noise power per unit bandwidth equal to that of the actual port at a specified frequency.

The total output noise power of a system may be represented in terms of an operating temperature (T_{op}). The operating temperature is attributed to noise generated both inside and outside the system.

3.3.1 The total output noise power of the system (N_{to}) is represented by Equation 3.2.

$$N_{to} = GkB (T_i + T_e) \qquad (3.2)$$

G = System Gain

T_i = Noise temperature of the input termination which delivers the incident input noise power.

T_e ... Effective input noise temperature of the system.

B Bandwidth of the system under test.

3.3.2 The effective operating temperature is defined by Equation 3.3.

$$T_{op} = T_i + T_e \qquad (3.3)$$

3.4 NOISE FIGURE (NOISE FACTOR)

"Noise Figure" and "Noise Factor" are synonymous terms. The 1957 IRE definition reads as follows: "The average noise factor (average noise figure) of a 2-port transducer is the ratio of (1) The total noise power delivered by the transducer into its output termination when the noise temperature of its input termination is standard (290 degrees K) at all frequencies to (2) that portion (1) engendered by the input termination.

NOTE

For hetrodyned systems (2) includes only that noise from the input termination which appears at the output via the principle frequency transformation of the system and does not include spurious contributions such as those from an image frequency transformation. See Section 2.5.8 on Image Response Considerations.

[1] "Standards on Electron Tubes: Definition of Terms, 1957."

3.4.1 Noise figure can be expressed mathematically as in Equation 3.4.

$$F = \frac{N_o}{G N_I} \qquad (3.4)$$

F Noise figure expressed as a power ratio.

N_o Output noise power (290 degrees K at input termination.)

N_I Input noise power (290 degrees K at input termination) generated by input termination.

G System (Transducer) gain.

3.4.2 Input Noise power (N_I) can be further defined by Equation 3.5. (Reference Equation 3.1)

$$N = kTB \qquad (3.5)$$

T 290 degrees K.

B Bandwidth of the system (transducer)

3.4.3 Noise Figure in db is represented by Equation 3.6.

$$F_{db} = 10 \text{ Log}_{10} \frac{N_o}{GN_i} \tag{3.6}$$

3.4.4 Inserting Equation 3.1 and 3.2 into 3.4 we develop Equation 3.7.

$$F = \frac{Gkb\,T_i + T_e}{GkT_i B} = \frac{T_i + T_e}{T_i} \tag{3.7}$$

3.4.5 By definition T_i =290 degrees K, thus Equation 3.7 evolves into 3.

$$F = \frac{T_e}{290} + 1 \tag{3.8}$$

3.5 TECHNIQUES IN DETERMINING NOISE TEMPERATURE AND NOISE FIGURE FROM HOT-COLD MEASUREMENTS.

When the input of the system under test is connected to the hot termination (Temperature T_2), the total system output Noise power (N_{o2}) is given by Equation 3.9. (Reference 3.2)

$$N_{o2} = GkB(T_2 + T_e) \tag{3.9}$$

With the system connected to the Cold termination (Temperature (T_1), the total system output noise power (N_{o1}) is represented by Equation

$$N_{o1} = GkB(T_1 + T_2) \tag{3.10}$$

N_{o1} and N_{o2} are readily measureable as is the difference in power betweem them.

Y-Factor is defined as the ratio expressed in Equation 3.11.

$$Y = \frac{N_{o2}}{N_{o1}} \tag{3.11}$$

$$Y_{db} = 10 \text{ Log } \frac{N_{o2}}{N_{o1}} = 10 \text{ Log } N_{o2} - \text{Log } N_{o} \qquad (3.12)$$

The techniques outlined in Section 2.3 measure the Y-factor expressed in db (Y_{db}).

To determine Effective Input Noise Temperature from Y-factor, substitute Equations 3.9 and 3.10 into 3.11.

$$Y = \frac{T_2 + T_e}{T_1 + T_e} \qquad (3.13)$$

Solving for T_e we get:

$$Te = \frac{T_2 - YT_1}{Y-1} \qquad (3.14a)$$

In The Hot/Cold Noise Generator T_2 = 373.2 degrees K and T_1 = 77.3 degrees

$$T_e = \frac{295.9}{Y-1} - 77.3 \qquad (3.14b)$$

To determine the Noise Figure in terms of Y-factor, substitute the results of 3.14a into 3.8.

$$F = \frac{T_2 - YT_1}{290(Y-1)} + 1 \qquad (3.15)$$

Expressed in decibels, the noise figure computed using Equation 3.16.

$$F_{db} = 10 \text{ Log}_{10} \frac{T_2 - YT_1}{290(Y-1)} + 1 \qquad (3.16)$$

3.6 THEORY OF UNIT OPERATION

Hot and Cold noise is the result of the effects of temperature on a conductor. The Kay Model 3010 provides these outputs by means of isolated controlled temperature environments.

A highly stabilized oven is used for the development of Hot noise. This oven maintains a temperature of 373.2 degrees Kelvin. Once the oven has reached its operating temperature, regulation and maintenance of this temperature will be indicated by the on and off fluctuating of the oven temperature light. A copper/constantan thermocouple provides temperature information for the use of an externally coupled temperature indicator. The Hot noise termination is inserted into this environment thus giving off a calculable noise which is conveyed to the Hot output connector.

Cold noise generation is a result of the cold termination being held at a temperature of 77.3 degrees K. Temperature stability, being the critical factor involved, is accomplished by the use of liquid Nitrogen, which boils at 77.3 degrees K. This boiling (Change to a gaseous state) takes place when the liquid Nitrogen

is subjected to an environment of a higher temperature. This boil off is minimized by the use of a "Dewar" flask (vacuum bottle) as a receptacle for the liquid Nitrogen. It is made up of a sealed double walled chamber, the area between the walls containing a vacuum. The flask is horizontally mounted in the unit with a vertically mounted input line, for filling. The external opening of this input line is secured by a Locking cap. The Cold termination is inserted into the flask by means of a port that passes through the stainless steel bulkhead. The bulkhead is insulated by a thick layer of polyurethane foam.

The cold chamber is so designed, that, if proper filling techniques are employed, there is little chance of Oxygen contamination, of the Nitrogen or Oxygen liquifying inside the termination (Thus, causing high SWR).

SECTION IV

Maintenance

4.1 Introduction

The Kay Model 3010 Hot-Cold Noise Generator has been designed and manufactured to provide great reliability and ease of operation. There are, however, certain preventive maintenance actions necessary for the assurance of this reliability. These actions will be covered in this section.

In the event any malfunctions are discovered, during the preventive maintenance checks or normal operation, there are certain measures to be taken. These measures are covered in the corrective maintenance part of this section.

In the event that a particular repair cannot be accomplished at the users facility, the KAY ELEMETRICS' Service Department should be notified.

4.2 Preventive Maintenance

The Check-out procedure (Section 2.2), in addition to providing an initial unit operational check, is extremely valuable in the assessment of possible and probable malfunction sources. Performance of the check-out procedure, on a regular basis, is necessary only in a case where the unit is under constant use. Long dormant periods of none use, will in no way affect the units operational capability.

The most critical point in preventive maintenance is the effect of liquid Nitrogen contamination. Care should be taken at all times to insure that foreign matter is not added to the flask. Oxygen contamination of the liquid Nitrogen, in particular, is the cause of erroneous Cold noise outputs. This problem occurs with icing of the area around the termination, thus changing termination temperature.

4.3 TROUBLESHOOTING

The Check Out Procedure (Section 2.2) is a good aid in ascertaining the existance and the nature of unit malfunctions. The SWR checks (Hot and Cold) are especially helpful, since an out of specification ratio is the result of most malfunctions in operation. In addition to a SWR check, the termination(s) DC resistance should be checked. The resistances for either termination should fall within 45 and 55 ohms. A reading out of this range indicates a mechanical separation or breakage, of the termination(s) in question. In this event, it is suggested that the generator be returned to the factory for corrective action. (See Section VI for reshipment instructions). A unit schematic has been provided (Section V) and should prove to be an additional aid in troubleshooting. Although not advised, if extreme care is taken, the Hot and Cold output RF connectors may be removed for inspection, of the air line, for moisture or for replacement. The steps involved are as follows:

1. Remove unit cover by removing three upper front and rear panel screws. Also remove six side panel screws.

2. Remove connector mounting plates.

3. Remove front panel.

4. Hold the "Flat" on the stainless steel rod securely, not allowing it to turn. At this time, unscrew the connector shell.

5. Unscrew the pin and remove the bead from air line. Do not flex the center conductor, of the air line, more than necessary.

When replacing the pin and bead, finger tighten the bead only, as the termination resistor will bear the brunt of the torque. Follow the previous steps, starting with step 4 and back through 1, for refitting the connector.

NOTE

It is suggested that the previous procedure be performed, only when deemed absolutely necessary. Under normal conditions the unit should be returned to the factory for such action. (See Section VI for reshipment instructions.)

4.4 CORRECTIVE MAINTENANCE

If Cold noise generation is out of specification, liquid Oxygen contamination of the termination may be the problem. Proceed as follows:

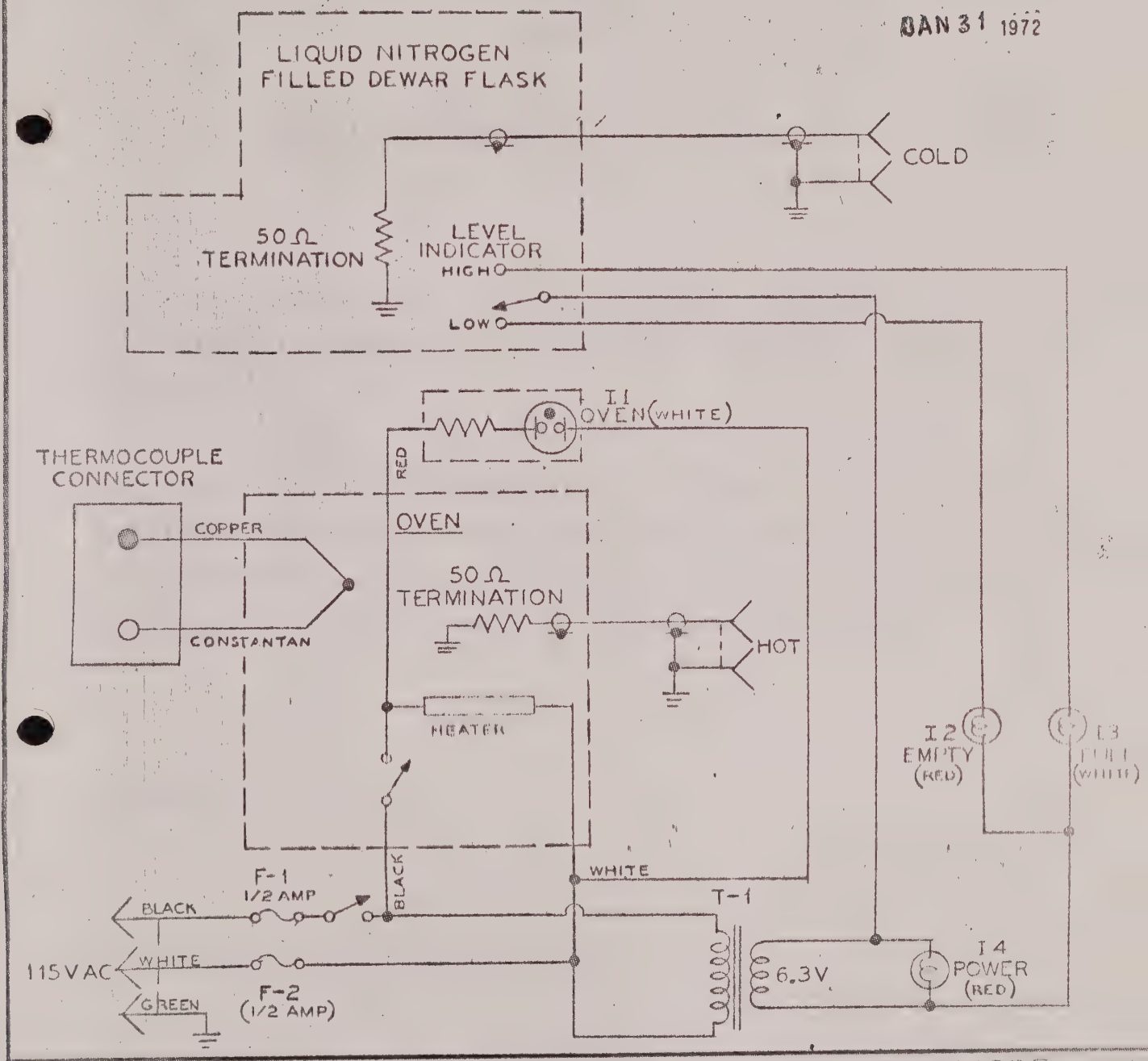
1. Gently tip the unit forward, for about 30 seconds, by raising the rear feet by about 2½ inches above the counter surface.

2. Recheck the SWR. An improved ratio should result, if not, continue tipping. If, at the end of a reasonable period, there is no improvement in SWR, it may be due to water being present in the termination. "Bake" the unit at 75 degrees C for several days. If, at the end of this period there is still no improvement in SWR, consult the factory service department for further aid.

If Hot noise generation is out of specification, the malfunction(s) is generally in the realm of factory repair. With the exception of replacing any easily accessible parts, contact should be made with the factory service department.

Note

Rinsing the flask with water may cause it to enter into the cold termination. If the flask must be rinsed, carefully flush it with liquid Nitrogen.



SECTION V

SCHEMATIC

SECTION VI

Reshipment Instructions

When returning equipment for any reason, it is necessary to secure permission from the factory or an accredited Kay representative before doing so.

When preparing the 3010 generator for shipping, please see that the instrument is securely wrapped and padded. A packing slip listing the shippers identification, instrument type and serial number, and a statement indicating the malfunction should be included.

HOT-COLD NOISE GENERATOR 3010
ASSEMBLY #12059

Dwg. Symbol No.	Description	Kay Part No.	Manufacturer and Part No.
	Thermocouple Plug		Thermo Electric MLP
	Thermocouple Jack		Thermo Electric 25100-TK
S1	Switch S.P.S.T.		A H & H
T1	Transformer		Stancor P-6465
F1-F2	Fuse, (Pieces)		AGC ½A
J1-J2	Connector, (Pieces)		Amphenol #APC-7S 131-1066
I1 (one)	Lamp, Neon		G. E. AIG
I2,I3,I4	Lamp, (Pieces)		Drake #765
	Stopper		Scientific Glass #R-8120 Size #7
	Oven		CTS, Knights #900-0219-0
	Stopper Assembly	12680	Kay Elemetrics
	Terminal Strip	8666	Kay Elemetrics #8666
	Pilot Light with Lamp	8643W	Drake #121-7-204 White Lens
	Pilot Light with Lamp, (Pieces)	8643R	Drake #121-7-204 Red Lens
	Fuseholder, (Pieces)	243	Kay Elemetrics #243
	Light with Lamp		Drake #5130-546-173 White